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Fluid-Phase Behaviour for a Miscible-Gas-Injection EOR Project in a Giant Offshore Oil Field With Large Compositional Variations

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Abstract

Gas injection as an EOR method is being considered for the giant Al Shaheen field, located offshore Qatar. The field is characterized by large lateral variations in fluid properties across the field. The oil gravity ranges from 16 to 38 °API and significant variations in initial GOR and saturation pressure are observed. The field is developed with horizontal wells with up to 35,000 ft long reservoir sections. The oil gravity may vary considerably along a horizontal well, which needs to be considered when evaluating further field development options involving miscible as well as immiscible gas injection.

An extensive experimental program aimed at establishing a model for the miscibility behavior for this complex fluid system is described. The work resulted in the development of an equation of state (EOS) model capturing the miscibility behavior across the range of API gravities, as well as a set of black oil correlations consistent with the EOS.

A method for initializing compositional reservoir simulations with the developed EOS based on API, GOR and saturation pressure maps of the field was developed. This methodology allowed a finely discretized compositional variation to be represented in the compositional simulation models giving an accurate and detailed fluid phase behavior description.

Introduction

The Al Shaheen field is located in Block 5, off-shore Qatar, as seen in Figure 1. The field development started in 1992, details on the field history and layout can be found in the paper by Thomasen et al. [1]. The field is currently producing some 350,000 stb oil/d from two thin separate Cretaceous carbonate formations and an overlying sandstone formation. The field is developed with long horizontal wells placed partly in radial and partly in parallel line drive patterns of alternating water injectors and oil producers. A map of the current and planned well patterns for all reservoirs is seen in Figure 2.

The carbonate reservoirs are characterized by relatively thin oil columns with a large areal extent (25 km by 45 km) and fairly low permeable rock, with typical permeabilities in the 1-10 mD range. The PVT properties of the oil exhibit large lateral variations, with API gravities ranging from 16-38 °API within the same reservoir. The field has several gas caps and large variations in solution GOR and saturation pressures. A hypothesis for the origin of the complex fluid variations observed is that the reservoir has been charged by separate oil pulses followed by gas influx and biodegradation.

Further development studies are ongoing focusing on expansion of the current water flood scheme as well as EOR. One of the more promising EOR processes considered is Water-Alternating-Gas (WAG) injection using either CO₂ or hydrocarbon gas as injection gas. The reservoir simulation work supporting these studies includes both black oil and compositional modeling. The fluid property variations constitute a significant challenge in simulating the field performance, and the present work describes elements of the PVT data acquisition and PVT modeling workflows applied to support the simulation model development.

To capture the fluid property variations in both the black oil and compositional models, the simulation models are initialized based on a common set of maps of fluid properties, namely API gravity, GOR and saturation pressure. Examples of such maps are shown in Figures 3 and 4. To apply the maps in black oil simulations, a set of field specific black oil correlations has been developed by fitting the functional forms of common industry standard correlations to a large database of experimental PVT data for the field. The correlations are then applied by either generating region specific tables based on the maps or by